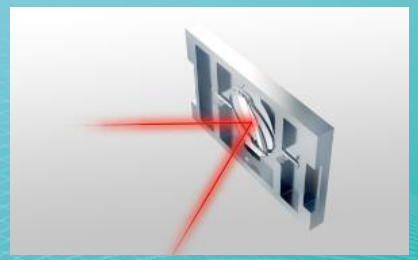
Fraunhofer IPMS

Fraunhofer-Institut für Photonische Mikrosysteme IPMS



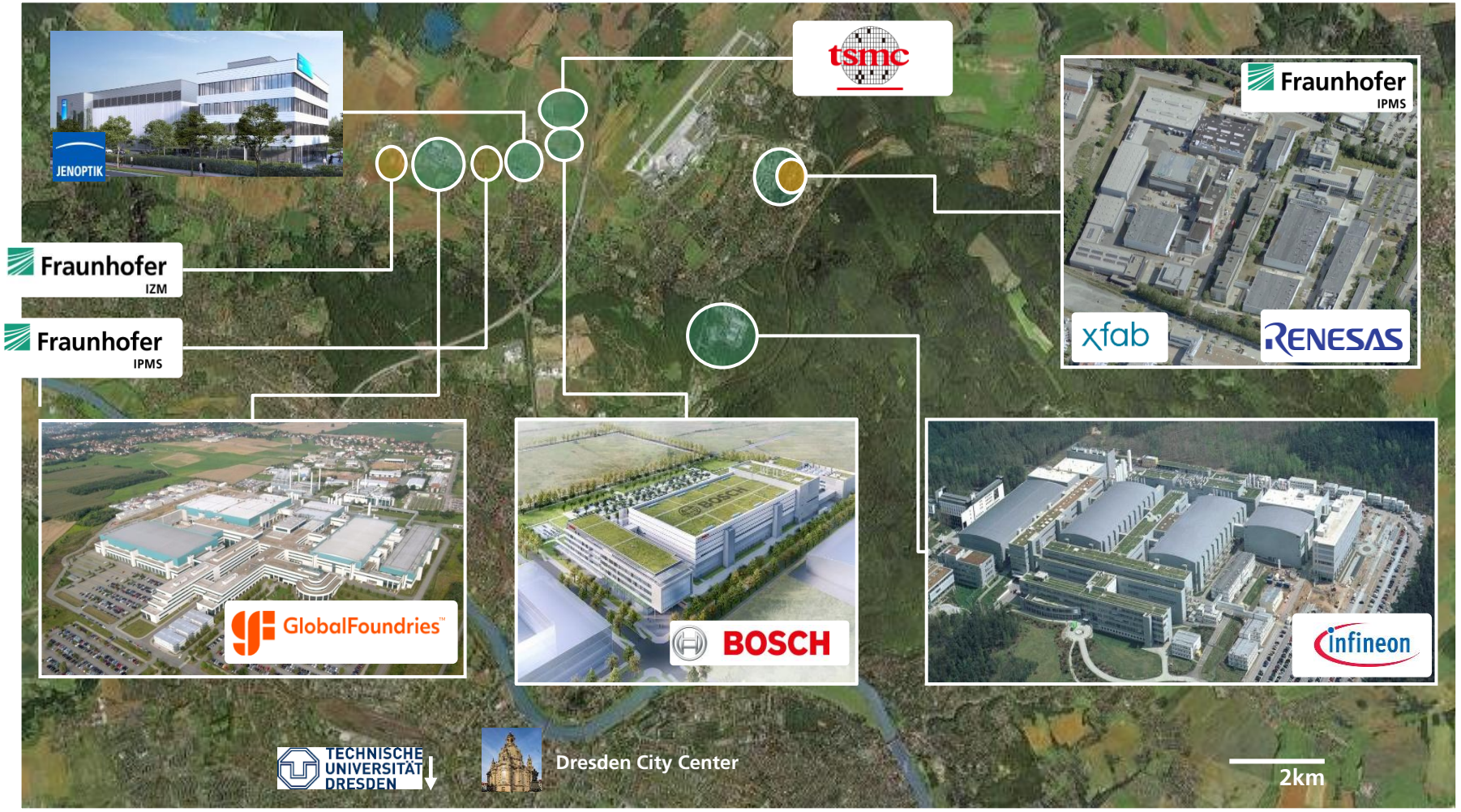
„O/LED Microdisplays for Near-to-eye wearables and Embedded Quantum-based Sensing“

U. Vogel & colleagues

Fraunhofer Institute for Photonic Microsystems IPMS, Dresden, Germany

Silicon Saxony -

The Heart of European Microelectronics Beats in Dresden



Silicon Saxony

Every third chip produced in Europe comes from Saxony.

Dr. Uwe Vogel
uwe.vogel@ipms.fraunhofer.de

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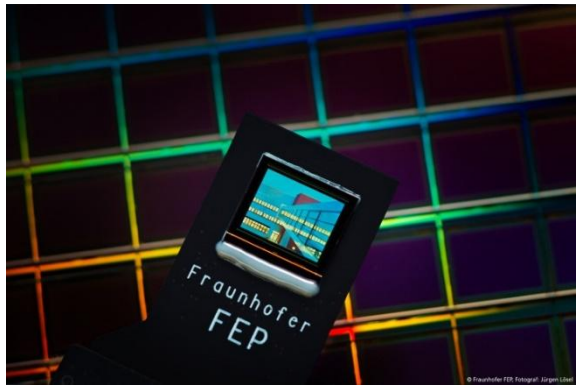
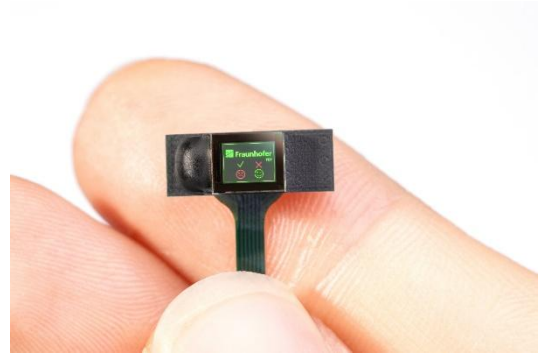
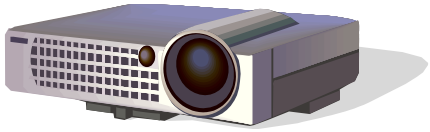
Microdisplays (general)

- Definition
  - Physically very small (<1.3”), yet
    - High information content (TV quality)
      - ≥1000ppi, i.e. pixel pitch ≤25x25µm,
      - typically 2..5µm dot pitch (i.e., 2000..3000..5000ppi)
    - Active matrix substrate (mostly CMOS)
    - Low power consumption
    - Enlarged image viewed through magnifying optics





- Applications
  - Projection
    - Rear projection
    - Front projection
    - Micro projection
  - Near-to-Eye (NTE)
    - Electronic Viewfinder (EVF)
    - Hand-held
    - Head/helmet Mounted
      - Professional, Consumer
      - Augmented-, Virtual-, Mixed-Reality (AR, VR, MR)



Dr. Uwe Vogel
uwe.vogel@ipms.fraunhofer.de

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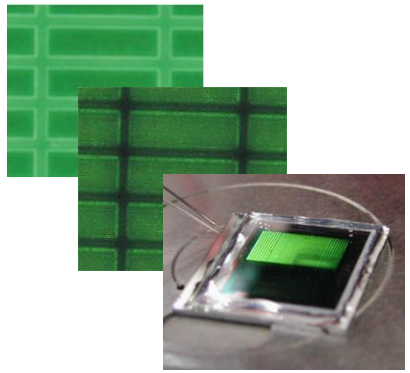
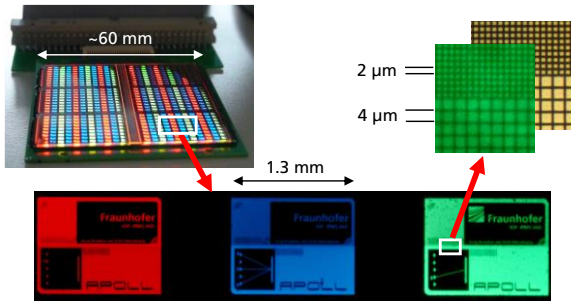
OLED microdisplay history (Roadmap based on customer requests) (1)

- Microdisplays



QVGA
0.16“, 6300dpi
9x11 patched array
Array colour

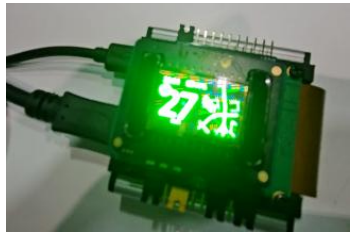


WUXGA
1“, 4618dpi
Full color

d: QVGA
0.19“, 4233dpi
Ultra-low power
Bi-color

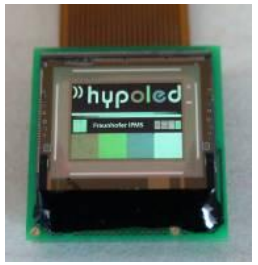
SXGA
0.62“, 7938dpi
Full color, high-voltage

WUXGA
1“, 2309dpi
high-current (microLED)



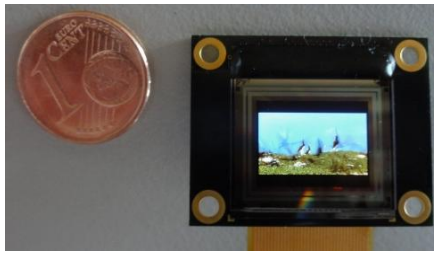
QVGA
0.24“, 5000ppi
Full color

VGA
0.4“, 6300ppi
Full color

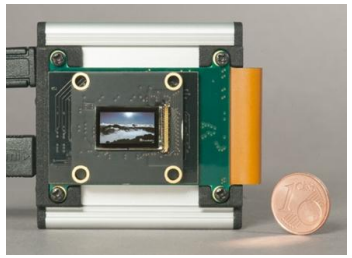


XGA, Rev 1
0.6“, 6300dpi
Full color

XGA, Rev 2
0.6“, 6300dpi
Full color



720p
0.64“, 4618dpi
Full color



1080p
0.19“, 10160dpi
Mono color

2k x 2k
1.1“, 5462dpi
High-voltage, LVDS

2007 — 2010 — 2016 — 2018 — 2025

Dr. Uwe Vogel
uwe.vogel@ipms.fraunhofer.de

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OLED microdisplay history (Roadmap based on customer requests) (2)

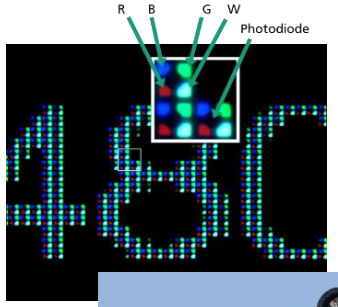
- Bi-directional, embedded sensing, semi-transparent, scanner

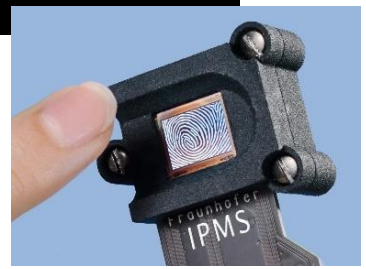
0.15“ d: 40x32, mono
s: 20x16, VIS

d: VGA, full color
s: 128x96, mono VIS/NIR
0.5“, 3200dpi

Embedded sensing (non-imaging reflection, flow, color)

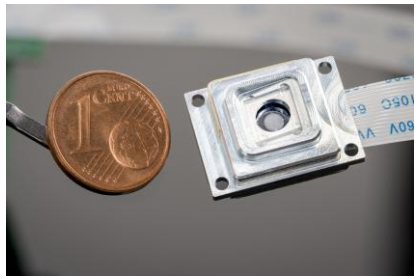
0.6“, d: SVGA, 3175dpi, full color;
s: SVGA, 1588dpi, mono



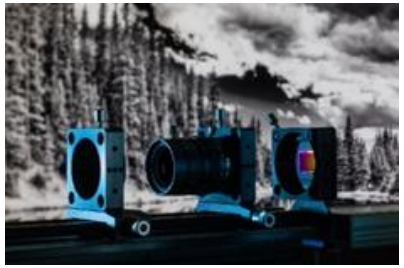


Embedded sensing (non-imaging chromophore excitation and readout)

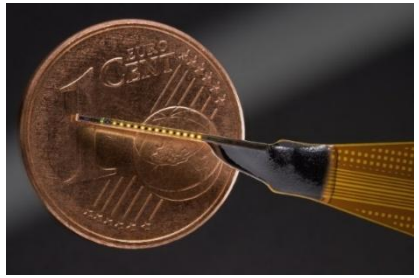
MEMS micro-scanning mirror

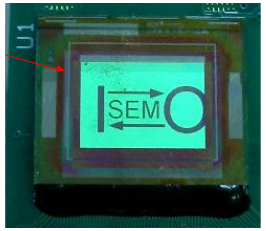


0.6“ SVGA OPD image sensor , NIR



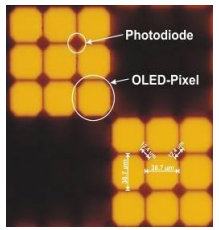
Active micro-optical probe

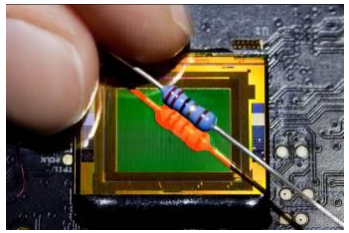




d: QVGA, mono
s: 160x120, mono VIS
0.6“, 700dpi

d: QVGA, area color + NIR
s: 160x120, mono VIS
0.6“, 700dpi





1“ WUXGA, 4618dpi, curved

0.7“ semi-transparent patched array, 7257dpi, mono

2007 — 2025

Dr. Uwe Vogel
uwe.vogel@ipms.fraunhofer.de

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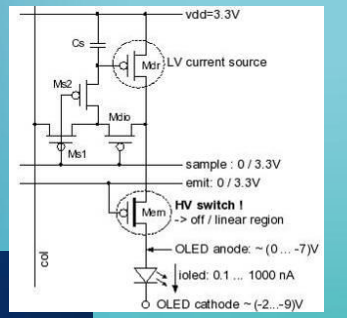
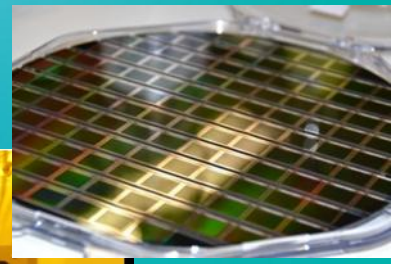
Core competences

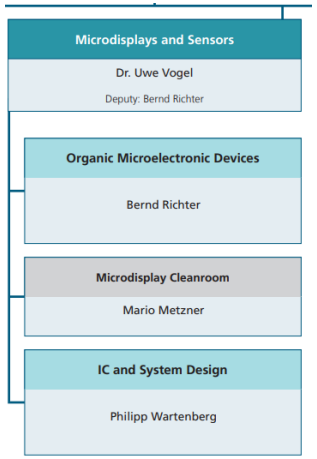
IC design (backplane, 8/12“ foundries)



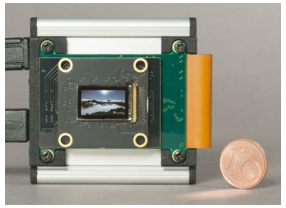
Emissive frontplane integration

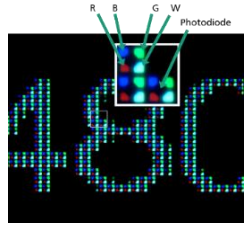


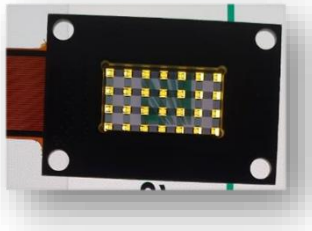
Organizational structure



Example outcomes







Dr. Uwe Vogel
uwe.vogel@ipms.fraunhofer.de

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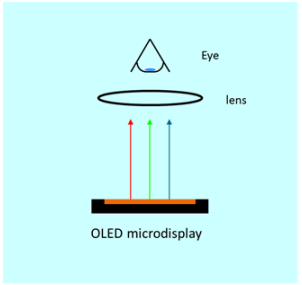
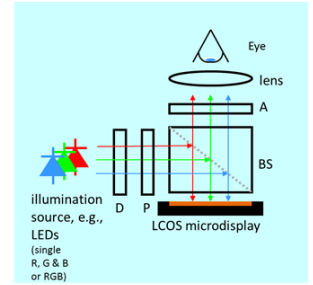
Microdisplay technology

Light source = image modulator

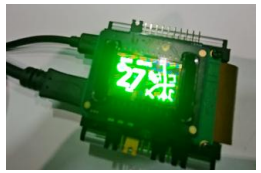
Light source ≠ image modulator

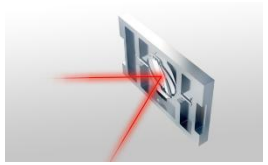
-> separate devices

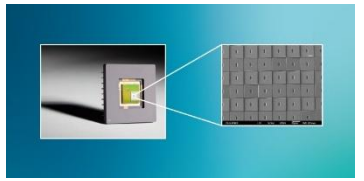


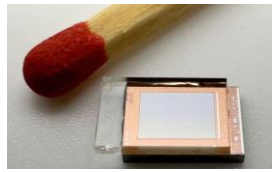


- Microdisplay technology
  - Emissive (non-transparent)
    - OLED-on-Silicon
    - microLED III/V-on-Si
  - transmissive
    - O/LED vs. LCD
  - scanning
    - MEMS scanner
  - reflective
    - MEMS SLM (DMD)
    - LCOS









Heterogeneous
Monolithic
Sole substrate
OLED-on-CMOS

Heterogeneous
Hybrid
Multiple substrates
µLED + CMOS

Dr. Uwe Vogel
uwe.vogel@ipms.fraunhofer.de

Figures: Examples of Fraunhofer IPMS microdisplay devices (LCOS, microLED: frontplane provided by third party)

Fraunhofer IPMS

Professional Use Case 1 - Full Video Display

- Application Scenario
  - **True augmented-reality**, VR
  - Real-time overlay of sensor / image data
- **Typ. Requirement**
  - **High-resolution** (720p, FHD, 4k…)
  - **High-framerate** (60Hz…120Hz)
  - Mono, multi, full-color
  - Extreme **low-** to extreme **high-brightness**
  - Typ. power >100mW
- System Consequence
  - Complex optics/electronics

***Low** Brightness* *U.S. Army @ Youtube*

Theon

***High** Brightness*

SA Photonics

Dr. Uwe Vogel
uwe.vogel@ipms.fraunhofer.de

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Use Case 2 - Information Display

- Application Scenario
  - **Assisted-reality/'light AR': Visualization of data** w/o overlay or augmentation
  - Mobile navigation, status information, logistics...

- **Typ. Requirement**
  - **Small, light-weight, no heat, long battery life**
  - Low- to mid-resolution (QVGA...VGA)
  - Low-framerate (0 ... 60Hz)
  - Extreme **low** to extreme **high brightness**
  - Typ. power **1mW**
  - Simple system

Dr. Uwe Vogel
uwe.vogel@ipms.fraunhofer.de

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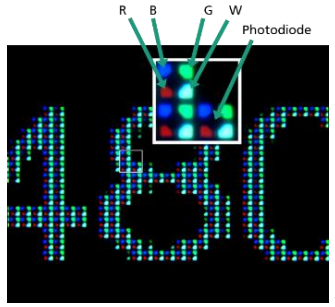
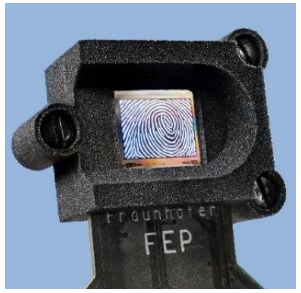
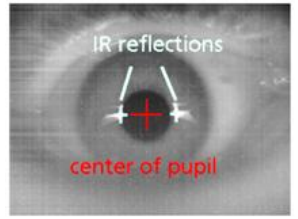
OLED-on-Silicon/CMOS: Unique Features, devices and applications

- **Bi-directional**
  - Display and image sensor in single chip
  - AR, VR, Eye-tracking; Optical fingerprint, Surface inspection, medical
- **Ultra-low power**
  - 1mW range: Wearables, electronic viewfinder, assisted-reality
- **Highest pixel density**
  - >10kdpi, deep sub-micron CMOS
- **Semi-transparent**
  - Combiner-less see-through AR
- **Large-area**
  - very high-definition (>FHD)
  - VR, AR, micro-projection
- **High-brightness**
  - High-current (microLED), high-voltage (stacked OLED)
- **NIR imager**
  - Organic photodiodes (OPD) on silicon CMOS
- **embedded sensors**
  - Gas or liquid process monitoring, e.g., O2, pH
- **Pilotfabrication- and Field-proven**

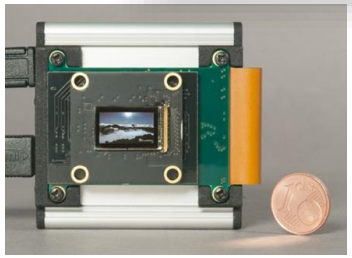


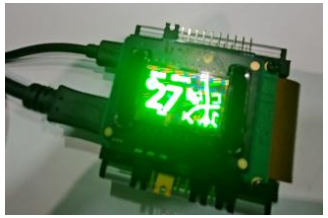









Dr. Uwe Vogel
uwe.vogel@ipms.fraunhofer.de

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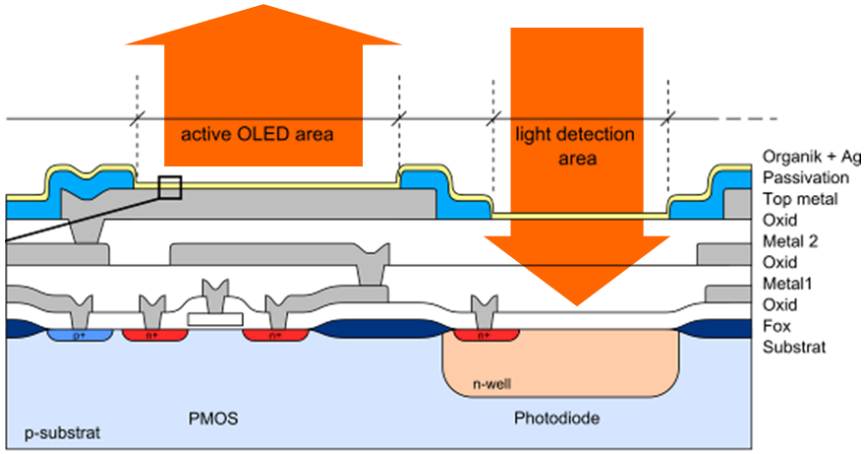
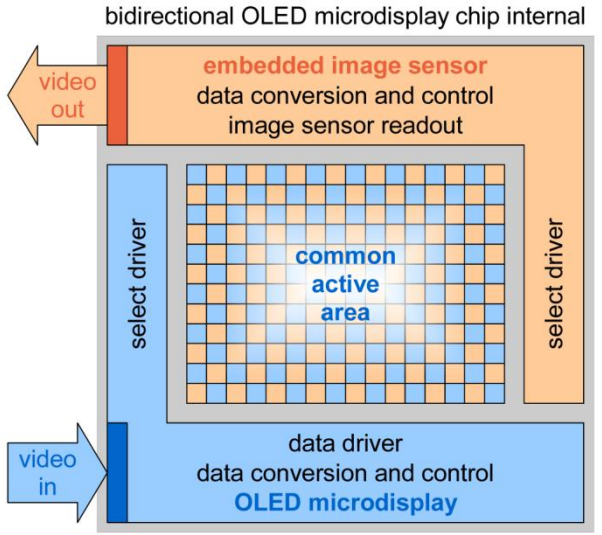
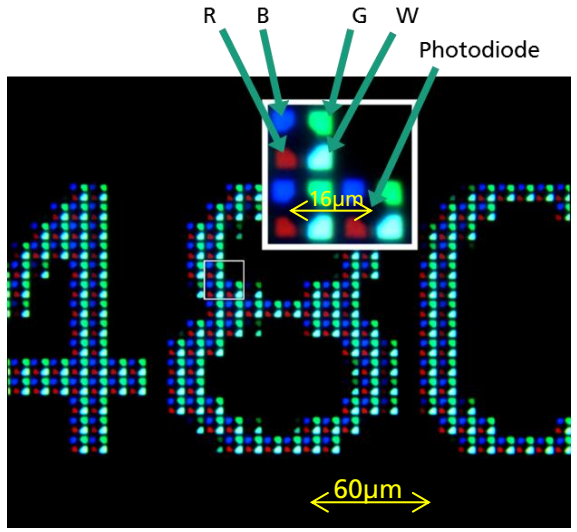
OLED-on-Silicon + embedded photodetectors/imager

- Highly-efficient high-res light source and imager on single chip
  - Bi-directional OLED microdisplay
  - Optoelectronic sensor w/ embedded
    - Patterened illumination
    - Excitation/stimulation
  - Spectral sensitivity photodetectors
    - CMOS: 400..900nm
    - OPD: 300..>1000nm







Dr. Uwe Vogel
uwe.vogel@ipms.fraunhofer.de

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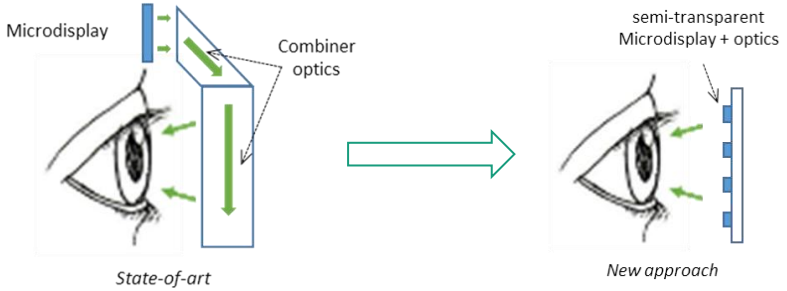
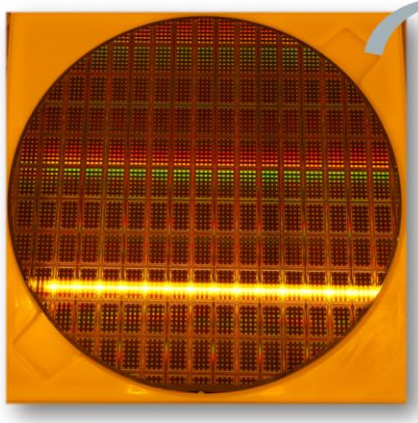
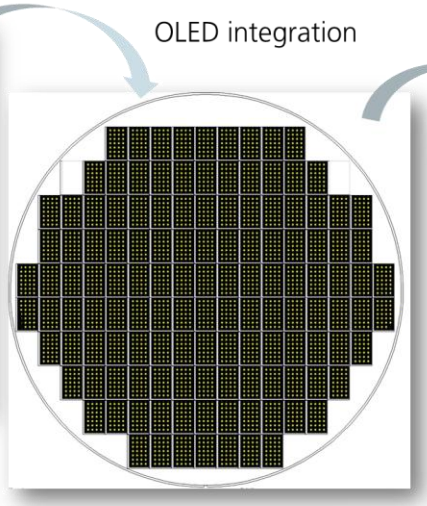
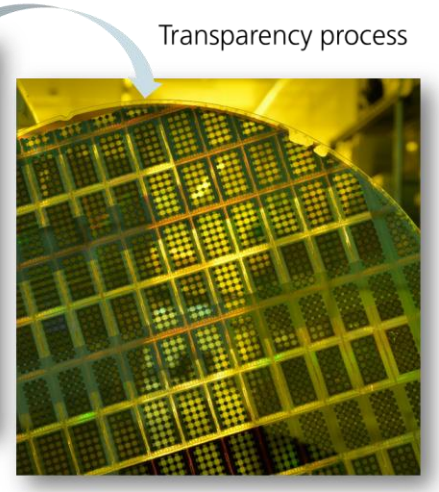
Semi-transparent OLED microdisplays for EPE-less optical see-through

- Waveguides typically require high-luminance light sources (due to low optical efficiency)
  - -> light engine high power consumption required -> too much for wearables (<1Wh)!
- Get rid of separate exit pupil expander (EPE), by making microdisplay backplane semi-transparent to become combiner itself




SOI CMOS wafer






Microoptics supported by Fraunhofer IOF


Initial AR demo with optics

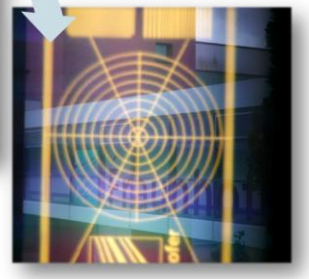
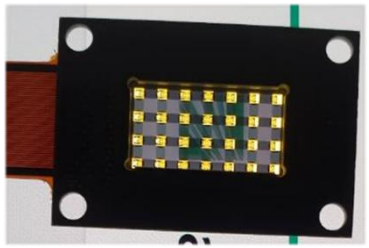
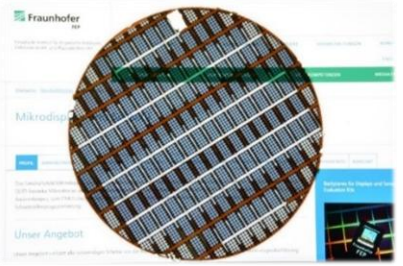


Image taken through optics



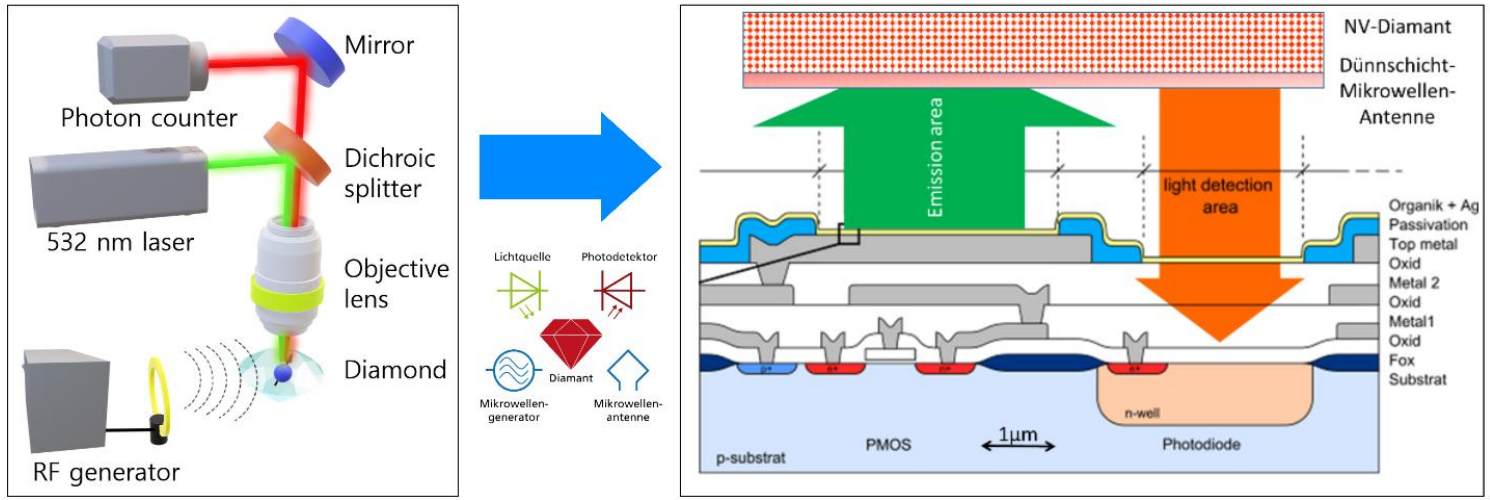


Dr. Uwe Vogel
uwe.vogel@ipms.fraunhofer.de

Fraunhofer IPMS

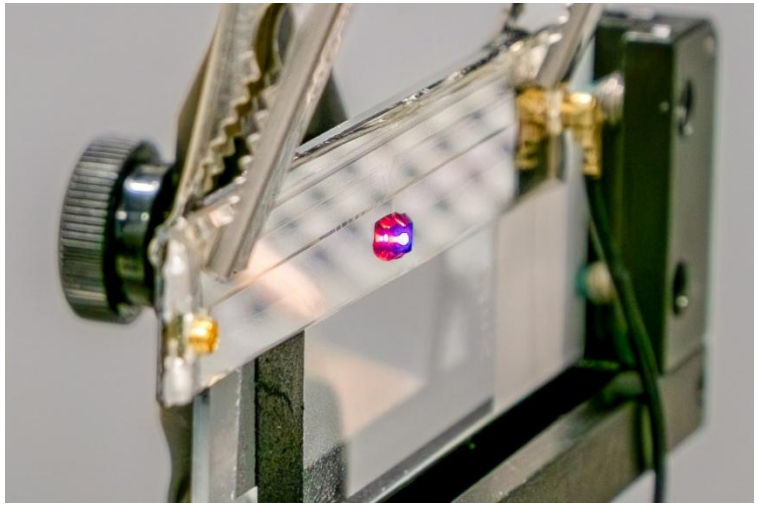
OptoQuant

- *CMOS-integrated, micro-optoelectronic room-temperature quantum-sensing for high-sensitivity magnetic field imaging*
  - Magnetic textures or electrical current imaging based on optical or scanning magnetometry with NV centers
  - CMOS-integrated NV sensor with built-in optical excitation, optical detection, and microwave generation and delivery
  - prototype with multiple channels of integrated sensor, to allow for imaging



Traditional NV sensor (meter scale)

CMOS-integrated NV sensor (µm scale)



Dr. Uwe Vogel
uwe.vogel@ipms.fraunhofer.de

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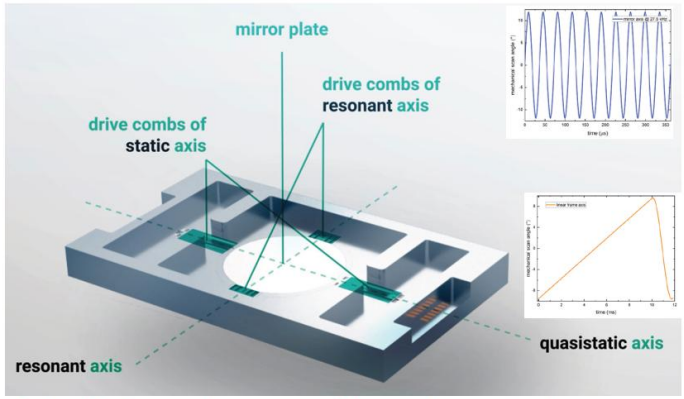
MEMS Scanning Mirrors

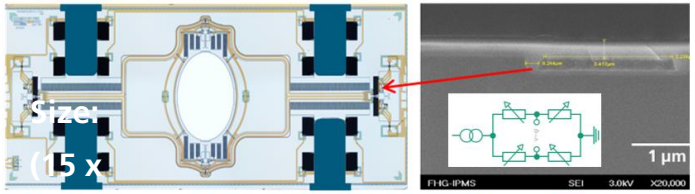
Electro-Static (monolithic)

2D-Raster MEMS-Scanner Technology:

USP: Monolithic integrated (PZR) Position Sensing



Setup of a Linscan microscanner with second resonant axis

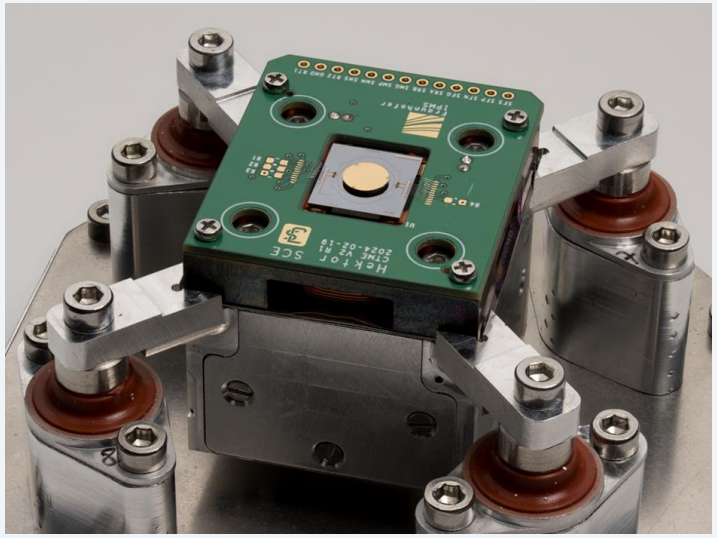


2D Resolin-Scanner QS-MSA: 9°; RS-MSA: 17° SEM-figure of PZR sensor

Electrostatic MEMS Vectorscanner:

- 1kHz,
- 2.4mm aperture

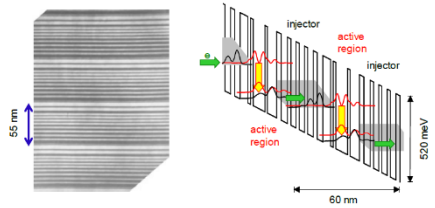
Electro-Magnetic (hybrid) *2D-Vectorscanner*



MEMS Vector Scanmodule with vibration isolation **for space LIDAR**

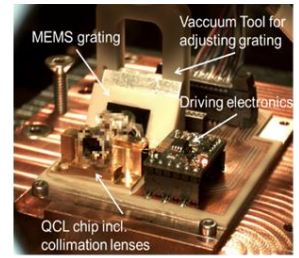
Parameter	Value
Large 2D-QS angle	**± 13 ° @ QS mech.**
Large aperture	**D = (5 … 10) mm**
Eigen-frequency	170…270 Hz or higher
actuating speed	(100 … 1000) °/s
driving current	ca. 20 mA/°

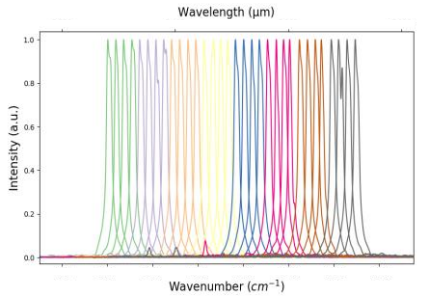
MIR tunable QCL – Quantum Cascade Laser

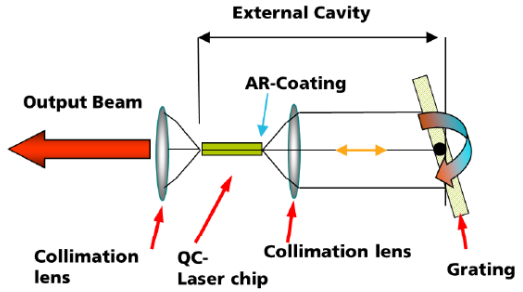


Left: SEM photo of epitaxial layers.
Right: Bandgap diagram of QCL

Integrated in µEC-QCL (IAF)







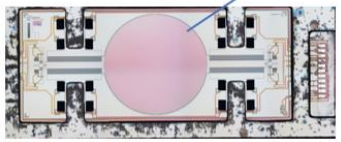
IAF / IPMS

- MOEMS scanning grating devices for broad band wavelength tuning of miniaturized EC-QCL
- Fabrication of resonant and quasi-static MOEMS devices with integrated diffraction gratings covering λ = **3…10 µm MIR range**

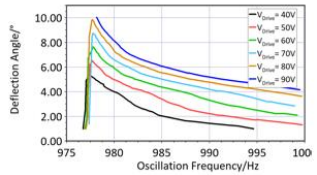
Resonant MOEMS grating

Ø5 mm IR diffraction grating

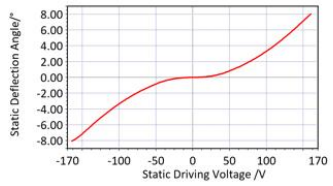
Quasi static MOEMS grating



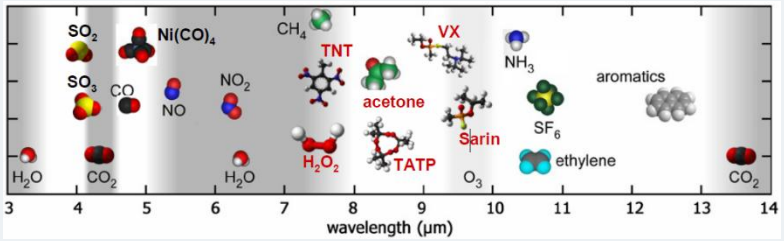
- scanning with 150 Hz, 500 Hz or 1 KHz rate ➔ 0.5 ms for one full spectral scan
- ±10° deflection for **broad tuning range**



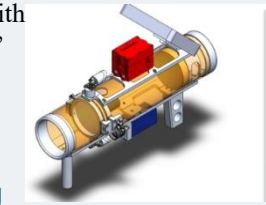
- tuning to single wavelength or arbitrary spectral scanning at 0…50 Hz scan rate ±8° deflection

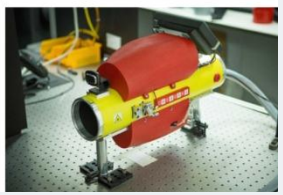


MIR tunable QCL - Quantum Cascade Laser

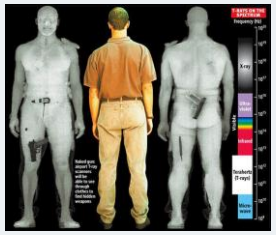


Example molecules with **mid-IR "fingerprint"** signatures.





- **Remote Sensing**
- **Trace gases detection**
- **Non-contact explosives detection**
- **Through-solidus-sensing** and **THz Imaging**
- infrared countermeasures (IRCM)
- beacons (combat identification)



ABC detection tank Fuchs (D)

QCL-based airport security scanner

Applications: MEMS *Vector* Scanners

Compact LiDAR sensors for Space:

- **Rendezvous- and Docking Sensors**
- **Service robotics / maintenance of satellites**
- **removing of space debris**
- **Rover Navigation of moon / planet missions**

Aviation:

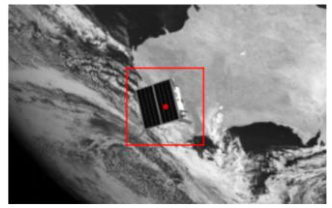
- **Obstacle detection e.g. for fast low-altitude flight of helicopters**

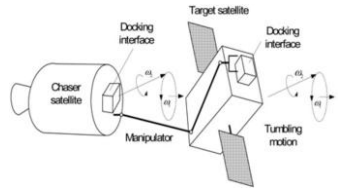
Security:

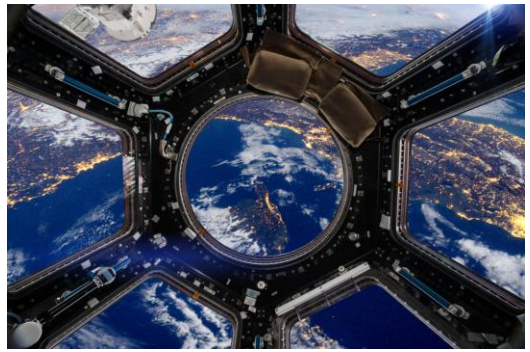
- **Monitoring of critical infrastructure**
- **3D surveying with drones**

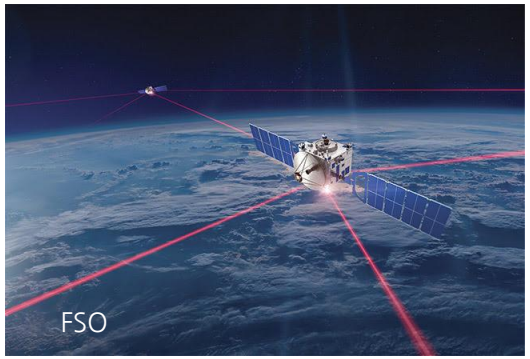
Free Space optical communication (FSO)

© ESA/D.Ducros - 2007





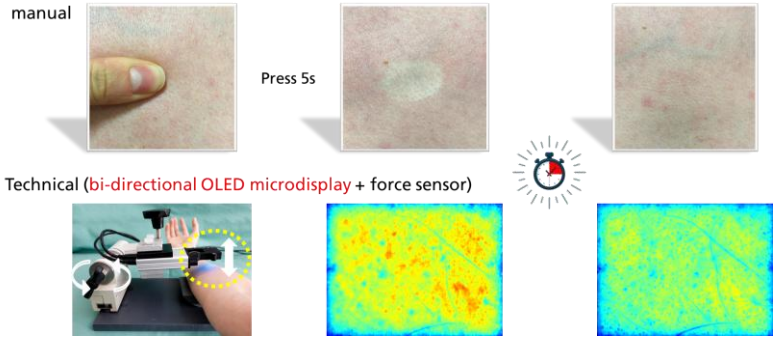


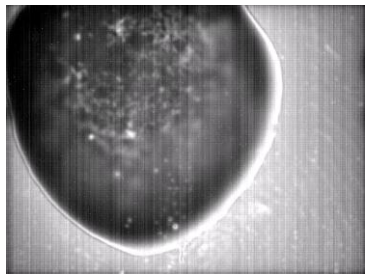


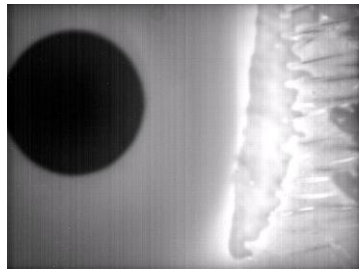
Fraunhofer IPMS

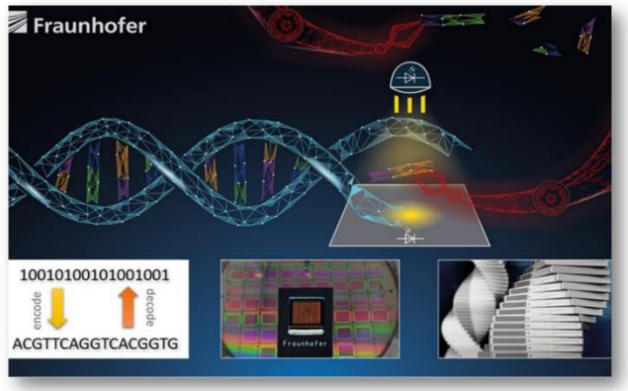
Outlook: O/LED-on-Silicon/microdisplays features and applications

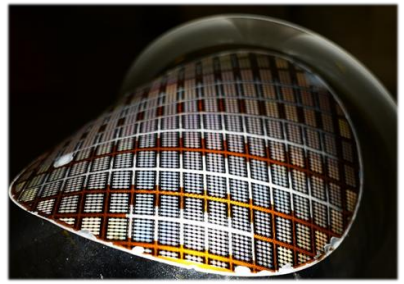
- high-brightness
  - see-through near-to-eye @ sun light condition
  - embedded projection
  - Medical and biologial applications, e.g., optogenetic brain/nerve interfaces, emergency medicine, microbiological synthesis
- high-resolution
  - Pixel densities >10kppi
    - Light-field and holographic displays
    - smaller chip size, lower cost
- (embedded) sensing
  - Single-chip image converter
  - Quantum sensors (very-low magnetic fields)
- (embedded) computing/connectivity
  - Edge Vision + Edge AI
  - Deep sub-micron CMOS process backplanes on 300mm (LVDS, MIPI, Bluetooth)
- extended spectral emission and detection range
  - UV, IR; α, β, γ; µLED
- New form factors, e.g., *transparent & curved microelectronics*
  - e.g., smart contact lens display
- Manufacturing processes: yield, production costs











Dr. Uwe Vogel
uwe.vogel@ipms.fraunhofer.de

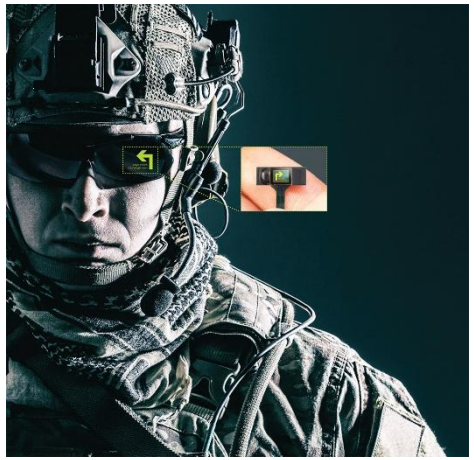
Fraunhofer IPMS

In-person Conference Announcement

"Augmented Vision: Displays for Defense"

March 16./17. 2026 (Mo/Tue)

Hosted by LusoVu in Lisbon/Portugal



- Venue: Jupiter Hotel Lisbon
- Schedule:
  - 1st day: Mon, March 16
    - Morning:
      - Virtual Worlds Association (VWA) Workshop on Future "XR chips & components pilot-line"
      - LusoSpace company tour (reservation required)
    - Afternoon (1pm+): sessions
    - evening event at rooftop Jupiter Hotel (sponsored by LusoVu)
  - 2nd day: Tue, March 17, 9am..3pm: sessions
- Speakers:
  - Portuguese Army (PT), Bundeswehr (DE), Portuguese Navy (PT), ENGO (FR), L3Harris (US), Polar Light Technologies (SE), FlexEnable (UK), Dispelix (FI), LusoVu (PT), MicroOled (FR), Schmidt & Bender (DE), CEA-LETI (FR), Fraunhofer (DE),...

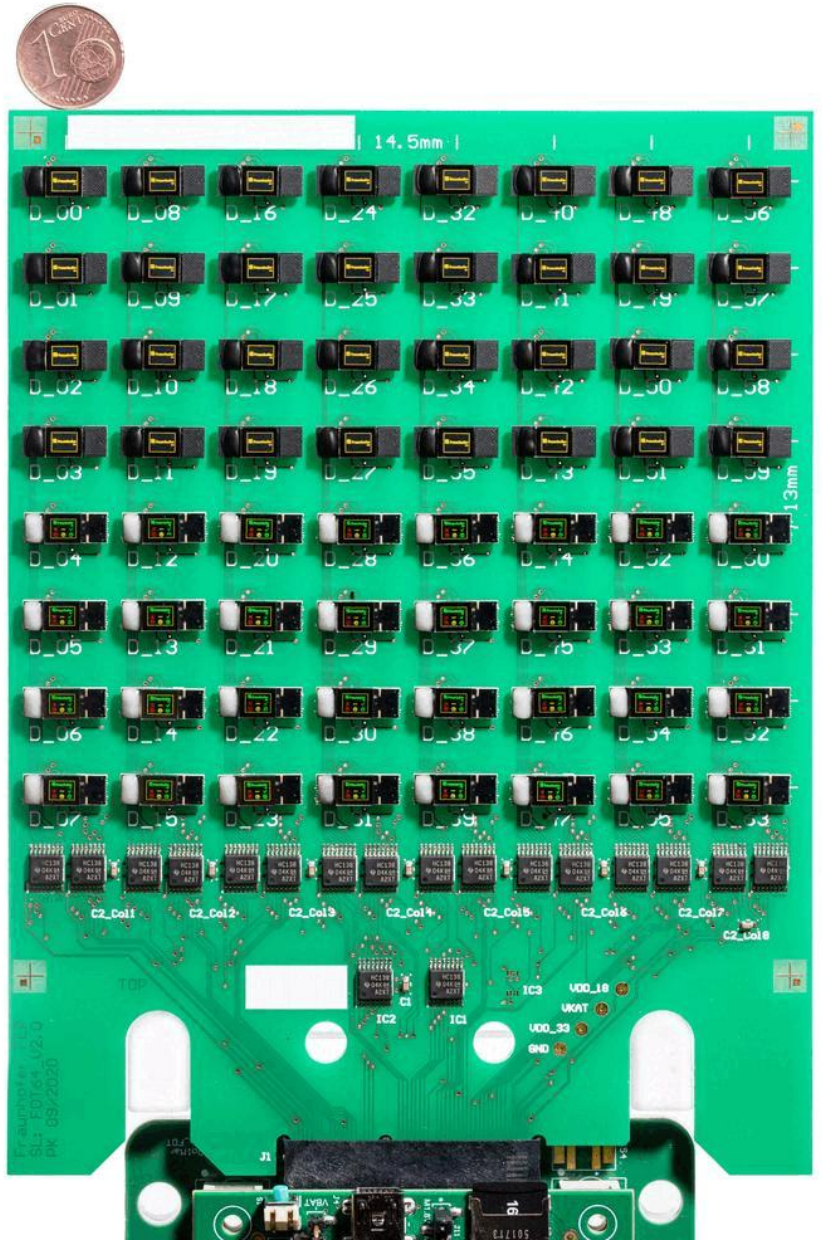
Ines Cadilha
LusoVU Lda
Executive Chair

Dr. Uwe Vogel
Fraunhofer Institute for Photonic Microsystems IPMS
General Chair

https://www.sid.org/Chapters/Europe/Mid-Europe, ME-SID@sid.org

Thanks for your attention!

- Offer
  - R&D on Customer-/applications-specific components and devices,
  - Manufacturing technology, pilot-fabrication
  - Private and publicly funded collaborative projects
  - Technology transfer/licensing
- Seek
  - Application specifications
  - Devices/technology evaluation (pilot studies)
  - System integration (optics, electronics, sensors, communication,…)
  - Applications (viewfinder, image converter, AR/VR/MR, sensing, …), end user



- Dr. *Uwe Vogel*
  - Division Director „Microdisplays and Sensors“
  - Fraunhofer Institute for Photonic Microsystems IPMS
    - Maria-Reiche-Strasse 2, D-01109 Dresden
    - phone: +49-151-12174078
    - email: uwe.vogel@ipms.fraunhofer.de

- Chair „Society for Information Display“ Mid-Europe Chapter (https://www.sid.org/Chapters/Europe/Mid-Europe#6501368-home)
- Chair GMM FA4.2 „Photonics & Microoptics“
- Chair DKE UK742.7 „Electronic Displays“ (DENC IEC TC110 mirror „Electronic Displays“)